

FORM PTO-1390  
(REV. 5-93)

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE ATTORNEY'S DOCKET NUMBER

TRANSMITTAL LETTER TO THE UNITED STATES  
DESIGNATED/ELECTED OFFICE (DO/EO/US)  
CONCERNING A FILING UNDER 35 U.S.C. 371

UNMC 63117A-US

U.S. APPLICATION NO. (IF EDOWEL HAS 37 C.F.R. 1.5)

09/445656

INTERNATIONAL APPLICATION NO.

INTERNATIONAL FILING DATE

PRIORITY DATE CLAIMED

PCT/US98/12139

11 June 1998

13 June 1997

TITLE OF INVENTION COMPOSITIONS FOR DELIVERY OF BIOLOGICAL AGENTS AND METHODS FOR  
THE PREPARATION THEREOF

APPLICANT(S) FOR DO/EO/US

KABANOV, Alexander V.; EISENBERG, Adi; KABANOV, Victor A.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information.

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
  - a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
  - b. ☒ has been transmitted by the International Bureau.
  - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
  - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
  - b. ☐ have been transmitted by the International Bureau.
  - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
  - d. ☐ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☐ A **FIRST** preliminary amendment.  
☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☐ Other items or information:

Copy of Form PCT/IB/308  
Small Entity Form

09445656 071700

APPLICATION NO. <u>09/145656</u> not assigned		INTERNATIONAL APPLICATION NO. PCT/US98/12139		ATTORNEY'S DOCKET NUMBER UNMC 63117A					
17. <input checked="" type="checkbox"/> The following fees are submitted: <div style="margin-left: 20px;"> <b>Basic National Fee (37 CFR 1.492(a)(1)-(5)):</b>            Search Report has been prepared by the EPO or JPO.....             International preliminary examination fee paid to USPTO (37 CFR 1.482)            .....            No international preliminary examination fee paid to USPTO (37 CFR 1.482)            but international search fee paid to USPTO (37 CFR 1.445(a)(2))..             Neither international preliminary examination fee (37 CFR 1.482) nor            international search fee (37 CFR 1.445(a)(2)) paid to USPTO.....             International preliminary examination fee paid to USPTO (37 CFR 1.482)            and all claims satisfied provisions of PCT Article 33(2)-(4).....         </div>				<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th style="text-align: left; padding: 2px;">CALCULATIONS</th> <th style="text-align: left; padding: 2px;">PTO USE ONLY</th> </tr> <tr> <td colspan="2" style="height: 100px;"></td> </tr> </table>		CALCULATIONS	PTO USE ONLY		
CALCULATIONS	PTO USE ONLY								
<b>ENTER APPROPRIATE BASIC FEE AMOUNT =</b>				\$ 96.00					
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				\$ 130.00					
Claims	Number Filed	Number Extra	Rate						
Total Claims	18 -20 =	0	X 78	\$	0				
Independent Claims	1 -3 =	0	X 18	\$	0				
Multiple dependent claims(s) (if applicable)				+	\$				
<b>TOTAL OF ABOVE CALCULATIONS =</b>				\$ 226.00					
Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).				\$ 113.00					
<b>SUBTOTAL =</b>				\$ 113.00					
Processing fee of \$130.00 for furnishing the English translation later the <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				+ \$ 0					
<b>TOTAL NATIONAL FEE =</b>				\$ 113.00					
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property +				\$ 0					
<b>TOTAL FEES ENCLOSED =</b>				\$ 113.00					
				Amount to be:					
				refunded	\$				
				charged	\$				
a. <input checked="" type="checkbox"/> A check in the amount of \$ <u>113.00</u> to cover the above fees is enclosed.									
b. <input type="checkbox"/> Please charge my Deposit Account No. _____ in the amount of \$ _____ to cover the above fees. A duplicate copy of this sheet is enclosed.									
c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. <u>04-1406</u> . A duplicate copy of this sheet is enclosed.									
<b>NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.</b>									
<div style="display: flex; justify-content: space-between;"> <div style="width: 60%;"> <p>SEND ALL CORRESPONDENCE TO:</p> <p>Kathleen D. Rigaut, Ph.D., J.D.            DANN, DORFMAN, HERRELL AND SKILLMAN            1601 Market Street            Suite 720            Philadelphia, Pennsylvania 19103</p> </div> <div style="width: 35%; text-align: right;"> <p><i>Kathleen D. Rigaut</i>            SIGNATURE</p> <p>Kathleen D. Rigaut, Ph.D.            NAME</p> <p><u>43.047</u>            REGISTRATION NUMBER</p> </div> </div>									

002720 99354460

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant or Patentee: Kabanov et al.

Application or Patent No.: Not Yet Assigned

Filed or Issued, Concurrently Herewith

For: Compositions for delivery of biological agents and methods for the preparation thereof

**VERIFIED STATEMENT (DECLARATION) SUPPORTING ANOTHER'S CLAIM FOR  
SMALL ENTITY STATUS [37 CFR §1.9(f) AND §1.27(d)] - NONPROFIT ORGANIZATION**

I hereby declare that I am making this verified statement to support a claim by the above-identified applicant or patentee for small entity status for purposes of paying reduced fees with regard to the above identified invention described in

☐ the specification filed herewith  
☒ International Application \_\_\_\_\_, filed 11 June 1998 PCT/US98/12139  
☐ U.S. Patent No. \_\_\_\_\_, issued \_\_\_\_\_

I hereby declare that I am an official empowered to act on behalf of the nonprofit organization identified below:

**FULL NAME OF ORGANIZATION:**

**TYPE OF ORGANIZATION**

BOARD OF REGENTS OF THE  
UNIVERSITY OF NEBRASKA

- ☒ University or other institution of higher education  
☐ Tax exempt under U.S. Internal Revenue Code [26 USC §501(a) and  
☐ Nonprofit scientific or educational under statute of state of U.S.A.

**ADDRESS OF ORGANIZATION:**

Name of State:

Citation of Statute:

Regents Hall  
3835 Holdrege Street  
Lincoln, NE

- ☐ Would qualify as tax exempt under U.S. IRC if located in U.S.A.  
☐ Would qualify as nonprofit scientific or educational under statute of state of U.S.A. if located in U.S.A.  
Name of State:  
Citation of Statute:

I hereby declare that the nonprofit organization identified above qualifies as a nonprofit organization as defined in 37 CFR §1.9(e) for purposes of paying reduced fees under section 41(a) and (b) of Title 35, United States code to the above-identified invention.

I hereby declare that rights under contract or law have been conveyed to and remain with the nonprofit organization with regard to the above-identified invention.

If the rights held by the nonprofit organization are not exclusive, each individual, concern or organization known to have rights to the invention is listed below\* and the organization knows of no rights to the invention being held by any person, other than the inventor, who could not qualify as an independent inventor under 37 CFR §1.9(c) if that person had made the invention, or by any concern which would not qualify as a small business concern under 37 CFR §1.9(d) or by a nonprofit organization under 37 CFR §1.9(e).

**FULL NAME:**

**ADDRESS:**

☐ INDIVIDUAL ☐ SMALL BUSINESS CONCERN ☐ NONPROFIT ORGANIZATION

**FULL NAME:**

**ADDRESS:**

☐ INDIVIDUAL ☐ SMALL BUSINESS CONCERN ☐ NONPROFIT ORGANIZATION

**FULL NAME:**

**ADDRESS:**

☐ INDIVIDUAL ☐ SMALL BUSINESS CONCERN ☐ NONPROFIT ORGANIZATION

\* NOTE: Separate verified statements are required from each named person, concern or organization having rights to the invention owing to their status as small entities. (37 CFR §1.27)

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying the offset of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate (37 CFR §1.28(b)).

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

Name of Person Signing: David A. Crouse, PhD

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Board of Regents

Address:

Signature:

*David A. Crouse*

Date:

12/10/99

10445656-071700

PTO/PCT Rec'd 10 DEC 1999

COMPOSITIONS FOR DELIVERY OF  
BIOLOGICAL AGENTS  
AND METHODS FOR THE PREPARATION THEREOF

Alexander V. Kabanov  
Adi Eisenberg  
Victor A. Kabanov

Pursuant to 35 U.S.C. §202(c), it is hereby  
acknowledged that the U.S. Government has certain  
rights in the invention described herein, which was  
made in part with funds from the National Science  
Foundation.

FIELD OF THE INVENTION

The present invention relates to  
compositions for the delivery of biologically active  
substances, including, without limitation, therapeutic  
and diagnostic agents, and in particular to  
compositions comprising block ionomers and oppositely  
charge surfactants that exhibit combined properties of  
amphiphilic block copolymers and polyelectrolyte-  
surfactant complexes.

DESCRIPTION OF RELATED ART

Polyelectrolyte complexes from DNA and a  
block ionomer containing a nonionic water soluble  
segment, e.g., poly(ethylene oxide) (PEO), and a  
polycation segment have been recently proposed to  
facilitate delivery of macromolecules, e.g., nucleic  
acids, into living cells, as a means of implementing  
gene therapy. In these complexes, the charges of the  
DNA are neutralized by the polycation segments while  
the complex remains soluble due to the effect of the  
PEO segments. Such systems belong to a broader class  
of polyelectrolyte complexes formed by block ionomers.  
Published reports on complexes from PEO-*b*-poly(L-  
lysine) cation and PEO-*b*-poly( $\alpha$ - $\beta$ -aspartate) anion, as  
well as PEO-*b*-polymethacrylate anion and poly(N-ethyl-  
4-vinylpyridinium) cation have suggested that they

- 2 -

represent a new type of chemical entity, with combined properties of amphiphilic block copolymers and polyelectrolyte complexes. Such systems are reported to be stable and soluble in aqueous solution and can form a microphase from the neutralized polyion segments surrounded by a shell from PEO segments. In addition, these complexes appear to form micelle-like aggregates with a concentration dependence resembling those characterized by a critical micelle concentration (CMC). At the same time, these systems behave like regular polyelectrolyte complexes, in that they are salt-sensitive since they tend to dissociate as the salt concentration increases beyond a critical value. Furthermore, they have been shown to participate in substitution reactions involving neutralized polyion segments. These systems are produced as a result of a polyion coupling reaction after mixing polyelectrolyte components. The stability of such systems critically depends on the number of the salt bonds between interacting polyelectrolytes of opposite charge. It takes at least ten salt bonds to form a cooperative system (Papisov and Litmanovich, *Adv. Polym. Sci.*, 1988, 90: 139). Preferably, the number of salt bonds should be twenty or more. This means that the complexes do not form if the net charge of the molecules is less than the minimal number needed to form the required number of salt bonds, i.e., less than 10 to 20. If it is assumed that a minimal molecular mass of a charged unit in the molecule of a polyelectrolyte is about 70, then the molecular mass of the components in such system should be more than about 700, preferably more than about 1,400. In practice, however, many charged units have molecular masses of about 200 and more. Furthermore, many interacting molecules are weak bases or acids that at physiological pH are charged 20 to

30%. This shall put the minimal molecular mass of polyions in these systems at least 3 to 5 times higher, i.e., at least about 2,000 to 7,000.

Normally, the molecular masses of polynucleotides used in such systems are 8,000 to 10,000 and more. These systems, therefore, have a fundamental limitation in that they cannot be formed with substances having less than about 10-20 charges and molecular masses less than about 2,000-7,000.

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#### SUMMARY OF THE INVENTION

In accordance with one aspect of the present invention, there is provided a composition of matter comprising a supramolecular complex comprising as constituents a block copolymer, having at least one nonionic, water soluble segment and at least one polyionic segment, and at least one charged surfactant having hydrophobic groups, with the charge of the surfactant being opposite to the charge of the polyionic segment of the block copolymer. The constituents of the complex are bound by interaction between the opposite charges thereof and between surfactant hydrophobic groups. In compositions of the invention comprising an anionic surfactant having biological activity, however, such anionic surfactant has a net charge of no more than about 10, preferably 5.

The polyionic segment of the block copolymer may be polyanionic, in which case the surfactant is a cationic surfactant, or polycationic, in which case the surfactant is an anionic surfactant.

In accordance with another aspect of the present invention, a method is provided for preparation of the above-described composition in the form of vesicles. In performing the method of the invention a block copolymer, having at least one

nonionic, water soluble segment and at least one polyionic segment is mixed with a charged surfactant having hydrophobic groups, with the charge of the surfactant being opposite to the charge of the polyionic segment of the block copolymer. The ratio of the net charge of the surfactant to the net charge of the polyionic segment present in the block copolymer is between about .01 and about 100.

The compositions of the present invention afford many advantages over the above-mentioned, previously reported block ionomer-polyelectrolyte complexes. For example, the compositions of this invention can be used to improve the therapeutic index with relatively low-molecular mass biological agents, and biological agents having less than 10 charges. Further, they can facilitate administration of biological agents by increasing their aqueous solubility. They also increase the stability and decrease side effects of the biological agents in the body. They further increase bioavailability of the biological agent incorporated therein, after administration to the body. In addition the compositions of the invention provide for site-specific drug delivery and release in the sites with acidic pH, such as tumors, bacteria, stomach, muscle tissues, or sites with alkali pH such as the gastrointestinal tract. They further provide for compartment-specific delivery of both macromolecule and small molecule biological agents into cells by releasing the biological agent in early endosomes, and enhancing its transport in the cytoplasm and cellular compartments.

**BRIEF DESCRIPTION OF THE DRAWINGS**

**Figure 1** is a graphical representation of binding isotherms of cetylpyridinium bromide (1) and dodecylpyridinium bromide (2) to polyethylene oxide-block-poly(sodium methacrylate), in which  $\beta$ , a fraction of occupied binding sites, is plotted as a function of surfactant concentration.

**Figure 2** is a graphical representation of binding isotherms of doxorubicin (1) and rhodamine 123 (2) to polyethylene oxide-block-poly(sodium methacrylate), in which  $\beta$ , a fraction of occupied binding sites, is plotted as a function of biological agent concentration.

**Figure 3** is a graphical representation showing turbidity in mixtures of cetylpyridinium bromide and polyethylene oxide-block-poly(sodium methacrylate) (1) and cetylpyridinium bromide and poly(sodium methacrylate) (2), as a function of the composition of the mixture.

**Figure 4** graphically illustrates the zeta potential (Figure 4a) and effective diameter (Figure 4b) of particles formed in the mixture of cetylpyridinium bromide and poly(sodium methacrylate) at various ratios of the surfactant to the ionic units of block copolymer.

**Figure 5** shows the dependence of the degree of conversion in the polyion coupling reaction for the mixture of cetylpyridinium bromide and polyethylene oxide-block-polymethacrylic acid.

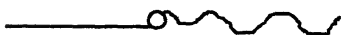
**DETAILED DESCRIPTION OF THE INVENTION**

Filed concurrently with this application is an application entitled "COMPOSITIONS FOR DELIVERY OF BIOLOGICAL AGENTS", Docket No. UNMC 63117B, with Alexander V. Kabanov, Adi Eisenberg and Victor A. Kabanov as the named inventors. The entire disclosure

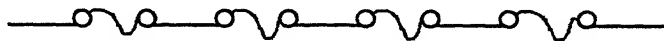
of Docket No. UNMC 63117B is hereby incorporated by reference herein.

The block copolymers used in the practice of this invention are most simply defined as conjugates of at least two different polymer segments (see, for example, Tirrel, *Interactions of Surfactants with Polymers and Proteins*. Goddard and Ananthapadmanabhan, Eds., pp. 59 et seq., CRC Press (1992)). Some block copolymer architectures are presented below:

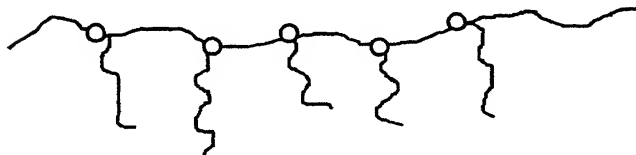
10

DiblockTriblock

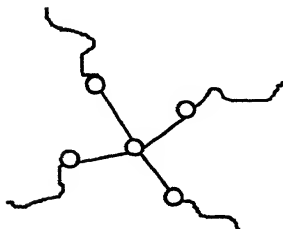
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Multiblock

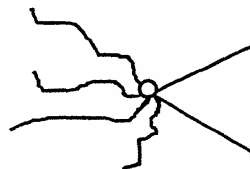
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25

Graft $(AB)_n$  Starblock

35

 $A_4B_2$  Starblock

5 The simplest block copolymer architecture contains two segments joined at their termini to give an A-B type diblock. Consequent conjugation of more than two segments by their termini yields A-B-A type triblock, ...ABAB... type multiblock, or even  
10 multisegment ...ABC... architectures. If a main chain in the block copolymer can be defined in which one or several repeating units are linked to different polymer segments, then the copolymer have a graft architecture, e.g.  $A(B)_n$  type. More complex architectures include for example  $(AB)_n$  or  $A_nB_m$  starblocks that have more than two polymer segments  
15 linked to a single center.

One method to produce block copolymers includes anionic polymerization with sequential addition of two monomers (see, for example, Schmolka, *J. Am. Oil Chem. Soc.* 1977, 54: 110; Wilczek-Vera et al., *Macromolecules* 1996, 29: 4036). This technique  
20 yields block copolymers with a narrow molecular mass distribution of the polymeric segments. Solid-phase synthesis of block copolymers has been developed recently that permit controlling the growth of the polymer segments with very high precision (Vinogradov et al., *Bioconjugate Chemistry* 1996, 7: 3). In some cases the block copolymers are synthesized by  
25 initiating polymerization of a polymer segment on ends of another polymer segment (Katayose and Kataoka, *Proc. Intern. Symp. Control. Rel. Bioact. Materials*, 1996, 23: 899) or by conjugation of complete polymer segments (Kabanov et al., *Bioconjugate Chem.* 1995, 6: 639; Wolfert et al., *Human Gene Ther.* 1996, 7: 2123). Properties of block copolymers in relation to this  
30 invention are determined by (1) block copolymer architecture and (2) properties of the polymer

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segments. They are independent of the chemical structure of the links used for conjugation of these segments (see, for example, Tirrel, *supra*; Sperling, *Introduction to Physical Polymer Science*, 2d edn., p. 46 et seq., John Wiley & Sons (1993)).

In one preferred embodiment the block copolymer is selected from the group consisting of polymers of formulas

10                   N-P, (P-N)<sub>n</sub>-P, N-(P-N)<sub>n</sub>, N-(P-N)<sub>n</sub>-P

wherein N is a nonionic, water soluble segment ("N-type segment"), P is polyionic segment ("P-type segment") and n is an integer from 1 to 5000. It is preferred that the degrees of polymerization of N-type and P-type segments are from about 3 to about 50000, more preferably from about 5 to about 5000, still more preferably from about 20 to about 500. If more than one segment of the same type comprise one block copolymer, then these segments may all have the same lengths or may have different lengths.

The preferred polyanion P-type segments include, but are not limited to those such as polymethacrylic acid and its salts, polyacrylic acid and its salts, copolymers of methacrylic acid and its salts, copolymers of acrylic acid and its salts, heparin, poly(phosphate), polyamino acid (e.g. polyaspartic acid, polyglutamic acid, and their copolymers containing a plurality of anionic units), polymalic acid, polylactic acid, polynucleotides, carboxylated dextran, and the like. Particularly preferred polyanion P-type segments are the products of polymerization or copolymerization of monomers which polymerize to yield a product having carboxyl pendant groups. Representative examples of such monomers include acrylic acid, aspartic acid 1,4-

phenylenediacrylic acid, citraconic acid, citraconic anhydride, trans-cinnamic acid, 4-hydroxy-3-methoxy cinnamic acid, p-hydroxy cinnamic acid, trans-glutaconic acid, glutamic acid, itaconic acid,  
5 linoleic acid, linolenic acid, methacrylic acid, maleic acid, maleic anhydride, mesaconic acid, trans- $\beta$ -hydromuconic acid, trans-trans muconic acid, oleic acid, ricinoleic acid, 2-propene-1-sulfonic acid, 4-styrene sulfonic acid, trans-traumatic acid,  
10 vinylsulfonic acid, vinyl phosphonic acid, vinyl benzoic acid and vinyl glycolic acid.

Preferred polycation P-type segments include but are not limited to polyamino acid (e.g., polylysine), alkanolamine esters of polymethacrylic  
15 acid (e.g., poly-(dimethylammonioethyl methacrylate), polyamines (e.g., spermine, polyspermine, polyethyleneimine), polyvinyl pyridine, and the quaternary ammonium salts of said polycation segments.

It is preferred to use nontoxic and  
20 non-immunogenic polymer-forming N-type and P-type segments. Because of elevated toxicity and immunogenicity of cationic peptides the non-peptide P-type segments are particularly preferred.

In the case of block copolymers having at  
25 least one polyanionic segment, the nonionic segment may include, without limitation, polyetherglycols (e.g. poly(ethylene oxide), poly(propylene oxide)) copolymers of ethylene oxide and propylene oxide, polysaccharides (e.g. dextran), products of  
30 polymerization of vinyl monomers (e.g., polyacrylamide, polyacrylic esters (e.g., polyacrolloyl morpholine), polymethacrylamide, poly(N-2-hydroxypropyl) methacrylamide, polyvinyl alcohol, polyvinyl pyrrolidone, polyvinyltriazole,  
35 N-oxide of polyvinylpyridine), polyortho esters, polyamino acids, polyglycerols (e.g., poly-2-methyl-2-

oxazoline, poly-2-ethyl-2-oxazoline) and copolymers and derivatives thereof.

Block copolymers comprising at least one polycationic segment may be similarly formulated using nonionic segments such as polyetherglycols (e.g., polyethylene glycol) or copolymers of ethylene oxide and propylene oxide. See, for example, Bronstein et al., Proc. Am. Chem. Soc., Division of Polymeric Materials: Science and Engineering, 76: 52 (1997); Kabanov et al., U.S. Patent 5,656,611; Spatz et al., Macromolecules, 29: 3220 (1996); Wolfert et al., Human Gene Ther., 7: 2123 (1996); Harada and Kataoka, Macromolecules, 29: 3220 (1996).

The term surfactant is used herein in a most general sense to encompass any surface active agent that is adsorbed at interface (see, for example, Martin, *Physical Pharmacy*, 4th edn., p. 370 et seq., Lea & Febiger, Philadelphia, London, 1993). These surface active agents in particular decrease the surface tension at the air-water interface in aqueous solutions (see, for example, Martin, *Physical Pharmacy*, 4th edn., p. 370 et seq., Lea & Febiger, Philadelphia, London, 1993) and include without limitation micelle forming amphiphiles, soaps, lipids, surface active drugs and other surface active biological agents, and the like (see, for example, Martin, *Physical Pharmacy*, 4th edn., Lea & Febiger, Philadelphia, London, 1993; Marcel Dekker, New York, Basel, 1979; Atwood and Florence, *J. Pharm. Pharmacol.* 1971, 23: 242S; Atwood and Florence, *J. Pharm. Sci.* 1974, 63: 988; Florence and Attwood, *Physicochemical Principles of Pharmacy*, 2nd edn., p. 180 et seq., Chapman and Hall, New York, 1988; Hunter, *Introduction to Modern Colloid Science*, p. 12 et seq., Oxford University Press, Oxford, 1993). The term cationic surfactant is used herein to encompass, without

limitation any surfactant that can produce cation groups in aqueous solution. This includes, without limitation strong bases (e.g., quaternary ammonium or pyridinium salts, and the like) that dissociate in aqueous solution to form cationic groups and relatively weak bases (e.g., primary amines, secondary amines, and the like) that protonate in aqueous solution to produce a cationic group as a result of an acidic-basic reaction. Similarly, the term anionic surfactant is used herein to encompass, without limitation any surfactant that can produce anionic groups in aqueous solution. This includes, without limitation strong acids and their salts (e.g., alkylsulfates, alkylsulfonates, alkylphosphonates, and the like) that dissociate in aqueous solution to form anionic groups and weak acids (e.g., carboxylic acids) that ionize in aqueous solution to produce an anionic group as a result of an acidic-basic reaction.

The charged surfactants that may be used in the practice of this invention are broadly characterized as cationic and anionic surfactants having hydrophobic/lipophilic groups, i.e., the groups poorly soluble in water, and/or revealing an ability to adsorb at water-air interface, and/or solubilize in organic solvents with low polarity and/or self-assemble in aqueous media to form a nonpolar microphase. The use of such compounds in an important feature of this invention. The interactions of hydrophobic groups of surfactant molecules with each other contribute to cooperative stabilization of the ionic complexes between the block copolymers and surfactants of the opposite charge in the compositions of the current invention, as will be further described below. Typically, the cationic surfactants will be lipophilic quaternary ammonium salts, lipopolyamines, lipophilic polyamino acids or a mixture thereof,

particularly those proposed heretofore as a constituent of cationic lipid formulations for use in gene delivery. Various examples of classes and species of suitable cationic surfactants are provided  
5 hereinbelow.

Cationic surfactants that can be used in the compositions of the invention include, but are not limited to primary amines (e.g., hexylamine, heptylamine, octylamine, decylamine, undecylamine,  
10 dodecylamine, pentadecyl amine, hexadecyl amine, oleylamine, stearylamine, diaminopropane, diaminobutane, diaminopentane, diaminohexane, diaminoheptane, diaminooctane, diaminononane, diaminodecane, diaminododecane), secondary amines  
15 (e.g., N,N-distearylamine, adrenolutin, adrenalone, adrenolglomerulotropin, albuterol, azacosterol, benzocetamine, benzydamine, carazolol, cetamolol, spirogermanium), tertiary amines (e.g., N,N',N'-polyoxyethylene(10)-N-tallow-1,3-diaminopropan  
20 e, acecainide, adiphenine hydrochloride, adinozalam, ahistan, alloclamide, allocryptopyne, almitrine, amitriptyline, anileridine, aprindine, bencyclane, benoxinate, biphenamine, brompheniramine, bucumolol, bufetolol, bufotenine, bufuralol, bunaftine,  
25 bunitrolol, bupranolol, butacaine, butamirate, butethamate, butofilolol, butoxycaine, butriptyline, captodiamine, caramiphen hydrochloride, carbetapentane, carbinoxamine, carteolol, cassaidine, cassaine, cassamine, chlorpromazine, dimenoxadol,  
30 dimethazan, diphehydramine, orphenandrine, pyrilamine, pyrisuccidianol, succinylcholine iodide, tetracaine, and the like), quaternary ammonium salts, which include aromatic and non-aromatic ring-containing compounds (e.g. dodecyltrimethylammonium bromide,  
35 hexadecyltrimethylammonium bromide, alkyltrimethylammonium bromide,

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tetradecyltrimethylammonium bromide, benzalkonium chloride, benzethonium chloride, benzoquinonium chloride, benzoxonium chloride, bibenzonium bromide, cetalkonium chloride, cethexonium bromide, benzyonium bromide, benzyldimethyldodecylammonium chloride, benzyldimethylhexadecylammonium chloride, benzytrimethylammonium methoxide, cetyltrimethylethylammonium bromide, dimethyldioctadecyl ammonium bromide (DDAB) (see, e.g., Whitt et al., *Focus*, 1991, 13: 8), methylbenzethonium chloride, decamethonium chloride, methyl mixed trialkyl ammonium chloride, methyl trioctylammonium chloride, N-alkyl pyridinium salts, N-alkylpiperidinium salts, quinaldinium salts, amprolium, benzylpyrinium, bisdequalinium halides, azonium and azolium salts such as anisotropine methylbromide, butropium bromide, N-butylscopolammonium bromide, tetrazolium blue, quinolinium derivatives (such as atracurium besylate), piperidinium salts, such as bevonium methyl sulfate and thiazolium salts, such as beclotiamine), 1,2-diacyl-3-(trimethylammonio)propane (acyl group = dimyristoyl, dipalmitoyl, distearoyl, dioleoyl), 1,2-diacyl-3-(dimethylammonio)propane (acyl group = dimyristoyl, dipalmitoyl, distearoyl, dioleoyl), 1,2-dioleoyl-3-(4'-trimethylammonio) butanoyl-sn-glycerol, 1,2-dioleoyl-3-succinyl-sn-glycerol choline ester, cholesteryl (4'-trimethylammonio) butanoate), heterocyclic amines (e.g., azacuculonol, azaperone, azatadine, benzetimide, benziperylon, benzylmorphine, bepridil, biperidene, budipine, buphanamine, buphanitine, butaperazine, butorphanol, buzepide, calycanthine, carpipramine), imidazoles (e.g., azanidazole, azathiopropine, bifonazole, bizantrene, butacanazole, cafaminol), triasoles (e.g., bitertanol), tetrazoles (e.g.,

- azosemide), phenothiazines (e.g., azures A, B, C), aminoglycans (e.g., daunorubicin, doxorubicin, carinomycin, 4'-epiadriamycin, 4-demethoxy-daunomycin, 11-deoxydaunorubicin,
- 5 13-deoxydaunorubicin, adriamycin-14-benzoate, adriamycin-14-actanoate, adriamycin-14-naphthaleneacetate), rhodamines (e.g. rhodamine 123), acridines (e.g. acranil, acriflavine, acrisorcin), dicationic bolaform electrolytes (C12Me6; C12Bu6),
- 10 dialkylglycetylphosphorylcholine, lysolecithin), cholesterol hemisuccinate choline ester, lipopolyamines (e.g., dioctadecylamidoglycylspermine (DOGS), dipalmitoyl phosphatidylethanolamidospermine (DPPES), N'-octadecylsperminecarboxamide
- 15 hydroxytrifluoroacetate, N',N''-dioctadecylspermine-carboxamide hydroxytrifluoroacetate, N'-nonafluoropentadecylsperminecarboxamide hydroxytrifluoroacetate, N',N''-dioctyl (spermincarbonyl)glycinamide hydroxytrifluoroacetate,
- 20 N'-(heptadecafluorodecyl)-N''-(nonafluoropentadecyl)-spermincarbonyl)glycinamide hydroxytrifluoroacetate, N'-[3,6,9-trioxa-7-(2'-oxaeicos-11'-enyl)heptaeicos-18-enyl]spermincarbonyl)glycinamide hydroxytrifluoroacetate, N'-(1,2-dioleoyl-sn-glycero-3-phosphoethanoyl)spermine
- 25 carboxamide hydroxytrifluoroacetate) (see, for example, Behr et al., *Proc. Natl. Acad. Sci.* 1989, 86: 6982; Remy et al., *Bioconjugate Chem.* 1994, 5: 647), 2,3-dioleyloxy-N-[2(spermine-carboxamido)ethyl]-N,N-dimethyl-1-propanaminiumtrifluoroacetate
- 30 (DOSPA) (see, for example, Ciccarone et al., *Focus* 1993, 15: 80), N<sub>I</sub>,N<sub>II</sub>,N<sub>III</sub>,N<sub>IV</sub>-tetramethyl-N,N<sub>I</sub>,N<sub>II</sub>,N<sub>III</sub>,N<sub>IV</sub>-tetrapalmitylspermine (TM-TPS) (Lukow et al., *J. Virol.* 1993, 67:4566), N-[1-(2,3-dioleyloxy)propyl]-N,N,N-trimethylamonium chloride (DOTMA) (see, for
- 35 example, Felgner, et al., *Proc. Natl. Acad. Sci. USA* 1987, 84: 7413; Ciccarone et al., *Focus* 1993, 15: 80),

1,2-dioleoyl-3-dimethyl-hydroxyethyl ammonium bromide (DORI) (see, for example, Felgner et al., *J. Biol. Chem.* 1994, 269:2550), 1,2-dioleyloxypropyl-3-dimethyl-hydroxyethyl ammonium bromide (DORIE) (see, for example, Felgner et al., *J. Biol. Chem.* 1994, 269:2550), 1,2-dioleyloxypropyl-3-dimethyl-hydroxypropyl ammonium bromide (DORIE-HP) (see, for example, Felgner et al., *J. Biol. Chem.* 1994, 269:2550), 1,2-dioleyloxypropyl-3-dimethyl-hydroxybutyl ammonium bromide (DORIE-HB) (see, for example, Felgner et al., *J. Biol. Chem.* 1994, 269:2550), 1,2-dioleyloxypropyl-3-dimethyl-hydroxypentyl ammonium bromide (DORIE-HPe) (see, for example, Felgner et al., *J. Biol. Chem.* 1994, 269:2550), 1,2-dimyristyloxypropyl-3-dimethyl-hydroxyethyl ammonium bromide (DMRIE) (see, for example, Felgner et al., *J. Biol. Chem.* 1994, 269:2550), 1,2-dipalmitoyloxypropyl-3-dimethyl-hydroxyethyl ammonium bromide (DPRIE) (see, for example, Felgner et al., *J. Biol. Chem.* 1994, 269:2550), 1,2-distearoyloxypropyl-3-dimethyl-hydroxyethyl ammonium bromide (DSRIE) (see, for example, Felgner et al., *J. Biol. Chem.* 1994, 269:2550), N,N-dimethyl-N-[2-(2-methyl-4-(1,1,3,3-tetramethylbutyl)-phenoxy]ethoxyethyl]-benzenemethanaminium chloride (DEBDA), N-[1-(2,3-dioleyloxy)propyl]-N,N,N,-trimethylammonium methylsulfate (DOTAB), lipopoly-L(or D)-lysine (see, for example, Zhou, et al., *Biochim. Biophys. Acta* 1991, 1065:8), poly(L (or D)-lysine conjugated to N-glutarylphosphatidylethanolamine lysine (see, for example, Zhou, et al., *Biochim. Biophys. Acta* 1991, 1065:8), didodecyl glutamate ester with pendant amino group ( $C_{12}GluPhC_n^+$ ) (see, for example, Behr, *Bioconjugate Chem.* 1994, 5:382), ditetradecyl glutamate ester with pendant amino group ( $C_{14}GluC_n^+$ ) (see, for example, Behr, *Bioconjugate Chem.* 1994, 5:382), 9-(N',N''-dioctadecylglycinamido)

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acridine (see, for example, Remy et al., *Bioconjugate Chem.* 1994, 5: 647), ethyl 4-[[N-[3-bis (octadecylcarbamoyl)-2-oxapropylcarbonyl]glycinamido]pyrrole-2-carboxamido]-4-pyrrole-2-carboxylate (see, 5 for example, Remy et al., *Bioconjugate Chem.* 1994, 5: 647), N',N'-dioctadecylornithylglycinamide hydropropyltrifluoroacetate (see, for example, Remy et al., *Bioconjugate Chem.* 1994, 5: 647), cationic derivatives of cholesterol (e.g., cholesteryl- 10 3(-oxysuccinamidoethylenetrimethylammonium salt, cholesteryl-3(-oxysuccinamidoethylenedimethylamine, cholesteryl-3(-carboxyamidoethylenetrimethylammonium salt, cholesteryl-3(- carboxyamidoethylenedi- 15 methylamine, 3([N-(N',N'-dimethylamino)octane-carbamoyl] cholesterol) (see, for example, Singhal and Huang, In *Gene Therapeutics*, Wolff, Ed., p. 118 et seq., Birkhauser, Boston, 1993), pH-sensitive cationic lipids (e.g., 4-(2,3-bis-palmitoyloxy-propyl)- 1-methyl-1H-imidazole, 4-(2,3-bis-oleoyloxy-propyl)-1- 20 methyl-1H-imidazole, cholesterol-(3-imidazol-1-yl propyl) carbamate, 2,3-bis-palmitoyl-propyl-pyridin-4-yl-amine) and the like (see, for example, Budker et al., *Nature Biotechnology* 1996, 14: 760).

Especially useful in the context of gene 25 delivery and other applications are compositions comprising mixtures of cationic surfactant and nonionic surfactants including, but not limited to dioleoyl phosphatidylethanolamine (DOPE), dioleoyl phosphatidylcholine (DOPC) (see, for example, Felgner, 30 et al., *Proc. Natl. Acad. Sci. USA* 1987; Singhal and Huang, In *Gene Therapeutics*, Wolff, Ed., p. 118 et seq., Birkhauser, Boston, 1993). This includes, in particular, commercially available cationic lipid compositions including but not limited to 35 LipofectAMINE™, Lipofectine®, DMRIE-C, CellFICTIN™, LipofectACE™, Transfectam reagents (see, for example,

Ciccarone et al., *Focus* 1993, 15: 80; Lukow et al., *J. Virol.* 1993, 67: 4566; Behr, *Bioconjugate Chem.* 1994, 5: 382; Singhal and Huang, In *Gene Therapeutics*, Wolff, Ed., p. 118 et seq., Birkhauser, Boston, 1993; 5 GIBCO-BRL Co.; Promega Co., Sigma Co) and other cationic lipid compositions used for transfection of cells (see, for example, Felgner et al., *J. Biol. Chem.* 1994, 269: 2550; Budker et al., *supra*.

The anionic surfactants that can be used in 10 the compositions of the present invention include, but are not limited to alkyl sulfates, alkyl sulfonates, fatty acid soaps, including salts of saturated and unsaturated fatty acids and derivatives (e.g., adrenic acid, arachidonic acid, 5,6-dehydroarachidonic acid, 15 20-hydroxyarachidonic acid, 20-trifluoro arachidonic acid, docosahexaenoic acid, docosapentaenoic acid, docosatrienoic acid, eicosadienoic acid, 7,7-dimethyl-5,8-eicosadienoic acid, 7,7-dimethyl-5,8-eicosadienoic acid, 20 8,11-eicosadiynoic acid, eicosapentaenoic acid, eicosatetraynoic acid, eicosatrienoic acid, eicosatriynoic acid, eladic acid, isolinoleic acid, linoelaidic acid, linoleic acid, linolenic acid, dihomog- $\gamma$ -linolenic acid,  $\gamma$ -linolenic acid, 25 17-octadecynoic acid, oleic acid, phytanic acid, stearidonic acid, 2-octenoic acid, octanoic acid, nonanoic acid, decanoic acid, undecanoic acid, undecelenic acid, lauric acid, myristoleic acid, myristic acid, palmitic acid, palmitoleic acid, heptadecanoic acid, 30 stearic acid, nonanedecanoic acid, heneicosanoic acid, docasanoic acid, tricosanoic acid, tetracosanoic acid, cis-15-tetracosenoic acid, hexacosanoic acid, heptacosanoic acid, octacosanoic acid, triocantanoic acid), salts of hydroxy-, hydroperoxy-, polyhydroxy-, 35 epoxy- fatty acids (see, for example, Ingram and Brash, *Lipids* 1988, 23:340; Honn et al.,

- Prostaglandins 1992, 44: 413; Yamamoto, *Free Radic. Biol. Med.* 1991, 10: 149; Fitzpatrick and Murphy, *Pharmacol. Rev.* 1989, 40: 229; Muller et al., *Prostaglandins* 1989, 38:635; Falgueyret et al., *FEBS Lett.* 1990, 262: 197; Cayman Chemical Co., 1994 Catalog, pp. 78-108), salts of saturated and unsaturated, mono- and poly-carboxylic acids (e.g., valeric acid, *trans*-2,4-pentadienoic acid, hexanoic acid, *trans*-2-hexenoic acid, *trans*-3-hexenoic acid, 2,6-heptadienoic acid, 6-heptenoic acid, heptanoic acid, pimelic acid, suberic acid, sebacic acid, azelaic acid, undecanedioic acid, decanedicarboxylic acid, undecanedicarboxylic acid, dodecanedicarboxylic acid, hexadecanedioic acid, docasenedioic acid, tetracosanedioic acid, agaricic acid, aleuritic acid, azafrin, bendazac, benfurodil hemisuccinate, benzylpenicillinic acid, p-(benzylsulfonamido)benzoic acid, biliverdine, bongkreikic acid, bumadizon, caffeic acid, calcium 2-ethylbutanoate, capobenic acid, carprofen, cefodizime, cefmenoxime, cefixime, cefazedone, cefatrizine, cefamandole, cefoperazone, ceforanide, cefotaxime, cefotetan, cefonicid, cefotiam, cefoxitin, cephamycins, cetiridine, cetraric acid, cetraxate, chaulmoorgic acid, chlorambucil, indomethacin, protoporphyrin IX, protizinic acid), prostanic acid and its derivatives (e.g., prostaglandins) (see, for example, Nelson et al., *C&EN* 1982, 30-44; Frolich, *Prostaglandins*, 1984, 27: 349; Cayman Chemical Co., 1994 Catalog, pp. 26-61), leukotrienes and lipoxines (see for example, Samuelsson et al., *Science* 1987, 237: 1171; Cayman Chemical Co., 1994 Catalog, pp. 64-75), alkyl phosphates, O-phosphates (e.g., benfotiamine), alkyl phosphonates, natural and synthetic lipids (e.g., dimethylallyl pyrophosphate ammonium salt, S-farnesylthioacetic acid, farnesyl pyrophosphate,

2-hydroxymyristic acid, 2-fluoropalmitic acid,  
inositoltriphosphates, geranyl pyrophosphate,  
geranylgeranyl pyrophosphate,  $\alpha$ -hydroxyfarnesyl  
phosphonic acid, isopentyl pyrophosphate,  
5 phosphatidylserines, cardiolipines, phosphatidic acid  
and derivatives, lysophosphatidic acids, sphingolipids  
and the like), synthetic analogs of lipids such as  
sodium-dialkyl sulfosuccinate (e.g., Aerosol OT®),  
n-alkyl ethoxylated sulfates, n-alkyl  
10 monothiocarbonates, alkyl- and arylsulfates (asaprol,  
azosulfamide, p-(benzylsulfonamideo)benzoic acid,  
cefonicid, CHAPS), mono- and dialkyl dithiophosphates,  
N-alkanoyl-N-methylglucamine, perfluoroalcanoate,  
cholate and desoxycholate salts of bile acids,  
15 4-chloroindoleacetic acid, cucurbitic acid, jasmonic  
acid, 7-epi jasmonic acid, 12-oxo phytodienoic acid,  
traumatic acid, tuberonic acid, abscisic acid,  
acitertin, and the like.

The preferred cationic and anionic  
20 surfactants of this invention also include  
fluorocarbon and mixed fluorocarbon-hydrocarbon  
surfactants. See, for example, Mukerjee, *P. Coll.  
Surfaces A: Physicochem. Engin. Asp.* 1994, 84: 1; Guo  
et al., *J. Phys. Chem.* 1991, 95: 1829; Guo et al., *J.*  
25 *Phys. Chem.*, 1992, 96: 10068. The list of such  
surfactants that are useful in the present invention  
includes, but is not limited to the salts of  
perfluoromonocarboxylic acids (e.g.,  
pentafluoropropionic acid, heptafluorobutyric acid,  
30 nonanfluoropentanoic acid, tridecafluoroheptanoic  
acid, pentadecafluorooctanoic acid,  
heptadecafluorononanoic acid, nonadecafluorodecanoic  
acid, perfluorododecanoic acid,  
perfluoropolycarboxylic acids, perfluorotetradecanoic  
35 acid) and the salts of perfluoro-polycarboxylic acids  
(e.g., hexafluoroglutaric acid, perfluoroadipic acid,

perfluorosuberic acid, perfluorosebacic acid), double tail hybrid surfactants,  $(C_mF_{2m+1})(C_nH_{2n+1})CH-OSO_3Na$  (see, for example, Guo et al., *J. Phys. Chem.*, 1992, 96: 6738, Guo et al., *J. Phys. Chem.* 1992, 96: 10068; Guo et al., *J. Phys. Chem.*, 1992, 96: 10068), fluoroaliphatic phosphonates, fluoroaliphatic sulphates, and the like.

The biological agent compositions of this invention may additionally contain nonionic or zwitterionic surfactants including but not limited to phospholipids (e.g. phosphatidylethanolamines, phosphatidylglycerols, phosphatidylinositols, diacyl phosphatidylcholines, di-O-alkyl phosphatidylcholines, platelet-activating factors, PAF agonists and PAF antagonists, lysophosphatidylcholines, lysophosphatidylethanol-amines, lysophosphatidylglycerols, lysophosphatidylinositols, lyso-platelet-activating factors and analogs, and the like), saturated and unsaturated fatty acid derivatives (e.g., ethyl esters, propyl esters, cholesteryl esters, coenzyme A esters, nitrophenyl esters, naphtyl esters, monoglycerids, diglycerids, and triglycerids, fatty alcohols, fatty alcohol acetates, and the like), lipopolysaccharides, glyco- and shpingolipids (e.g. ceramides, cerebrosides, galactosyldiglycerids, gangliosides, lactocerebrosides, lysosulfatides, psychosines, shpingomyelins, sphingosines, sulfatides), chromophoric lipids (neutral lipids, phospholipids, cerebrosides, sphingomyelins), cholesterol and cholesterol derivatives, Amphotericin B, abamectin, acediasulfone, n-alkylphenyl polyoxyethylene ether, n-alkyl polyoxyethylene ethers (e.g., Triton™), sorbitan esters (e.g. Span™), polyglycol ether surfactants (Tergitol™), polyoxyethylenesorbitan (e.g., Tween™), polysorbates, polyoxyethylated glycol

monoethers (e.g., Brij™, polyoxyethylene 9 lauryl ether, polyoxyethylene 10 ether, polyoxyethylene 10 tridecyl ether), lubrol, copolymers of ethylene oxide and propylene oxide (e.g., Pluronic™, Pluronic R™, 5 Teronic™, Pluradot™), alkyl aryl polyether alcohol (Tyloxapol™), perfluoroalkyl polyoxylated amides, N,N-bis[3-D-gluconamidopropyl]cholamide, decanoyl-N-methylglucamide, n-decyl  $\alpha$ -D-glucopyranozide, n-decyl  $\beta$ -D-glucopyranozide, 10 n-decyl  $\beta$ -D-maltopyranozide, n-dodecyl  $\beta$ -D-glucopyranozide, n-undecyl  $\beta$ -D-glucopyranozide, n-heptyl ( $\alpha$ -D-glucopyranozide, n-heptyl  $\beta$ -D-thiogluconopyranozide, n-hexyl  $\beta$ -D-glucopyranozide, n-nonanoyl  $\beta$ -D-glucopyranozide 15 1-monooleoyl-rac-glycerol, nonanoyl-N-methylglucamide, n-dodecyl  $\alpha$ -D-maltoside, n-dodecyl  $\beta$ -D-maltoside, N,N-bis[3-gluconamidepropyl]deoxycholamide, diethylene glycol monopentyl ether, digitonin, heptanoyl-N-methylglucamide, heptanoyl-N-methylglucamide, 20 octanoyl-N-methylglucamide, n-octyl  $\beta$ -D-glucopyranozide, n-octyl  $\alpha$ -D-glucopyranozide, n-octyl  $\beta$ -D-thiogalactopyranozide, n-octyl  $\beta$ -D-thiogluconopyranozide, betaine ( $R_1R_2R_3N^+R'CO_2^-$ , where  $R_1R_2R_3R'$  hydrocarbon chains), sulfobetaine 25 ( $R_1R_2R_3N^+R'SO_3^-$ ), phospholipids (e.g. dialkyl phosphatidylcholine), 3-[(3-cholamidopropyl)-dimethylammonio]-2-hydroxy-1-propanesulfonate, 3-[(3-cholamidopropyl)-dimethylammonio]-1-propanesulfonate, N-decyl-N,N-dimethyl-3-ammonio-1-propanesulfonate, N-dodecyl-N,N-dimethyl-3-ammonio-1-propanesulfonate, N-hexadecyl-N,N-dimethyl-3-ammonio-1-propanesulfonate, N-octadecyl-N,N-dimethyl-3-ammonio-1-propanesulfonate, N-octyl-N,N-dimethyl-3-ammonio-1-propanesulfonate, 30 N-tetradecyl-N,N-dimethyl-3-ammonio-1-propanesulfonate, dialkyl phosphatidylethanolamine.

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Surface active biological agents that may be used in the practice of this invention include those having utility in diagnostics or imaging, as well as those capable of acting on a cell, organ or organism to create a change in the functioning of the cell, organ or organism, including but not limited to pharmaceutical agents. Such biological agents include a wide variety of substances that are used in diagnostics, therapy, immunization or otherwise are applied to combat human and animal disease. Such agents include but are not limited to analgesic agents, anti-inflammatory agents, antibacterial agents, antiviral agents, antifungal agents, antiparasitic agents, tumoricidal or anti-cancer agents, toxins, hormones, neurotransmitters, immunomodulators, dyes, radiolabels, radio-opaque compounds, fluorescent compounds, cell receptor binding molecules, anti-glaucomic agents, mydriatic compounds and local anesthetics.

It is essential that the biological agents of this invention are charged, to form the complex with the block copolymer of the opposite charge. The term charged biological agent is used herein to encompass, without limitation any biological agent that can produce either cation or anion groups in aqueous solution. This includes, without limitation strong bases (e.g., quaternary ammonium or pyridinium salts, and the like) that dissociate in aqueous solution to form cationic group, and weak bases (e.g., primary amines, secondary amines, and the like) that protonate in aqueous solution to produce a cationic group as a result of an acidic-basic reaction. The anionic biological agents include without limitation strong acids and their salts (e.g., agents containing sulfate groups, sulfonate groups, phosphate groups, phosphonate groups and the like) that dissociate in

aqueous solution to form anionic group, and weak acids (e.g., carboxylic acids) that ionize in aqueous solution to produce an anionic group as a result of an acidic-basic reaction.

- 5           The biological agents which may be used in the compositions of the invention may include, but are not limited to non-steroidal anti-inflammatories, such as indomethacin, salicylic acid acetate, ibuprofen, sulindac, piroxicam, and naproxen, antiglaucomic  
10 agents such as timolol or pilocarpine, neurotransmitters such as acetylcholine, anesthetics such as dibucaine, neuroleptics such as the phenothiazines (e.g., compazine, thorazine, promazine, chlorpromazine, acepromazine, aminopromazine,  
15 perazine, prochlorperazine, trifluoperazine, and thioproperazine), rauwolfia alkaloids (e.g., reserpine and deserpine), thioxanthenes (e.g., chlorprothixene and tiotixene), butyrophenones (e.g., haloperidol, moperone, trifluoperidol, timiperone, and droperidol),  
20 diphenylbutylpiperidines (e.g., pimozide), and benzamides (e.g., sulpiride and tiapride); tranquilizers such as glycerol derivatives (e.g., mephesisin and methocarbamol), propanediols (e.g., meprobamate), diphenylmethane derivatives (e.g.,  
25 orphenadrine, benzotrapine, and hydroxyzine), and benzodiazepines (e.g., chlordiazepoxide and diazepam); hypnotics (e.g., zolpidem and butoctamide); beta-blockers (e.g., propranolol, acebutonol, metoprolol, and pindolol); antidepressants such as  
30 dibenzazepines (e.g., imipramine), dibenzocycloheptenes (e.g., amitriptyline), and the tetracyclics (e.g., mianserine); MAO inhibitors (e.g., phenelzine, iproniazid, and selegeline); psychostimulants such as phenylethylamine derivatives  
35 (e.g., amphetamines, dexamphetamines, fenproporex, phentermine, amfepramone, and pemoline) and

dimethylaminoethanols (e.g., clofenciclan, cyprodenate, aminorex, and mazindol); GABA-mimetics (e.g., progabide); alkaloids (e.g., codergocrine, dihydroergocristine, and vincamine); anti-Parkinsonism agents (e.g., L-dopamine and selegeline); agents utilized in the treatment of Alzheimer's disease, cholinergics (e.g., citicoline and physostigmine); vasodilators (e.g., pentoxifyline); and cerebro active agents (e.g., pyritinol and meclofenoxate).

Anti-neoplastic agents can also be used advantageously as biological agents in the compositions of the invention. Representative examples include, but are not limited to paclitaxel, daunorubicin, doxorubicin, carminomycin, 4'-epiadriamycin, 4-demethoxy-daunomycin, 11-deoxydaunorubicin, 13-deoxydaunorubicin, adriamycin-14-benzoate, adriamycin-14-actanoate, adriamycin-14-naphthaleneacetate, vinblastine, vincristine, mitomycin C, N-methyl mitomycin C, bleomycin A<sub>2</sub>, dideazatetrahydrofolic acid, aminopterin, methotrexate, cholchicine and cisplatin. Representative antibacterial agents are the aminoglycosides including gentamicin. Representative antiviral compounds are rifampicin, 3'-azido-3'-deoxythymidine (AZT), and acyclovir. Representative antifungal agents are the azoles, including fluconazole, macrolides such as amphotericin B, and candicidin.

Representative anti-parastic compounds are the antimonials. Suitable biological agents also include, without limitation vinca alkaloids, such as vincristine and vinblastine, mitomycin-type antibiotics, such as mitomycin C and N-methyl mitomycin, bleomycin-type antibiotics such as bleomycin A<sub>2</sub>, antifolates such as methotrexate, aminopterin, and dideaza-tetrahydrofolic acid,

taxanes, anthracycline antibiotics and others.

The compositions also can comprise enzyme inhibiting agents such as reverse transcriptase inhibitors, protease inhibitors, angiotensin converting enzymes, 5 $\mu$ -reductase, and the like. Typical of these agents are peptide and nonpeptide structures such as finasteride, quinapril, ramipril, lisinopril, saquinavir, ritonavir, indinavir, nelfinavir, zidovudine, zalcitabine, allophenylnorstatine, kynostatin, delaviridine, bis-tetrahydrofuran ligands (see, for example Ghosh et al., *J. Med. Chem.* 1996, 39: 3278), and didanosine. Such agents can be administered alone or in combination therapy; e.g., a combination therapy utilizing saquinavir, zalcitabine, and didanosine, zalcitabine, and zidovudine. See, for example, Collier et al., *Antiviral Res.* 1996, 29: 99.

Other suitable biological agents include oxygen transporters (e.g. porphines, porphirines and their complexes with metal ions), coenzymes and vitamins (e.g. NAD/NADH, vitamins B12, chlorophylls), and the like.

Suitable biological agents further include the agents used in diagnostics visualization methods, such as magnetic resonance imaging (e.g., gadolinium (III) diethylenetriamine pentaacetic acid), and may be a chelating group (e.g., diethylenetriamine pentaacetic acid, triethylenetriamine pentaacetic acid, ethylenediamine-tetraacetic acid, 1,2-diaminocyclo-hexane-N,N,N',N'-tetraacetic acid, N,N'-di(2-hydroxybenzyl) ethylene diamine), N-(2-hydroxyethyl) ethylene diamine triacetic acid and the like). Such biological agent may further include an alpha-, beta-, or gamma-emitting radionuclide (e.g., gallium 67, indium 111, technetium 99). Iodine-containing radiopaque molecules are also

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suitable diagnostic agents. The diagnostic agent may also include a paramagnetic or superparamagnetic element, or combination of paramagnetic element and radionuclide. The paramagnetic elements include but  
5 are not limited to gadolinium (III), dysprosium (III), holmium (III), europium (III) iron (III) or manganese (II).

The composition may further include a targeting group including but not limited to antibody,  
10 fragment of an antibody, protein ligand, polysaccharide, polynucleotide, polypeptide, low molecular mass organic molecule and the like. Such targeting group can be linked covalently to the block copolymer or surfactant, or can be non-covalently  
15 incorporated in the compositions through hydrophobic, electrostatic interactions or hydrogen bonds.

A new and unexpected finding of the present invention is that low molecular mass biological agents having from one to about five anionic groups can be  
20 formulated with block copolymers of opposite charge. The molecular masses of these biological agents are less than 4000, preferably less than 2000, still more preferably less than 700. It is further preferred that these biological agents contain a hydrophobic  
25 group providing for cooperative stabilization of the complex between the agent and block copolymer. Representative examples of biological agents that contain such a hydrophobic group include saturated and unsaturated fatty acids, arachidonic acid and  
30 derivatives, leukotrienes, porphyrines, anthracycline antibiotics, prostaglandins, benzodiazepines, and the like.

While not wishing to be bound by any particular theory, it is believed that the above-  
35 described surfactants and block copolymers of opposite charge form stable complexes due to cooperative

binding. (See, e.g., Goddard, In *Interactions of Surfactants with Polymers and Proteins*. Goddard and Ananthapadmanabhan, Eds., pp. 171 et seq., CRC Press, Boca Raton, Ann Arbor, London, Tokyo, 1992).

5 Cooperative binding occurs in the sense that binding of surfactant molecules to the block copolymer is enhanced by the presence of other molecules of the same or a different surfactant already bound to the same copolymer. According to the cooperative binding  
10 mechanism which is believed to underlie this invention, surfactant binds electrostatically to the oppositely charged P-type segments of the block copolymer to form supramolecular complexes. These complexes are cooperatively stabilized by the  
15 interactions of the hydrophobic parts of surfactant molecules bound to the same P-type segment with each other. Indeed, it appears that without these hydrophobic interactions, formation of the desired complex would not occur. Figure 1 presents the  
20 binding isotherms for interaction of cetylpyridinium bromide and dodecylpyridinium bromide with the polyethylene oxide-*block*-poly(sodium methacrylate) block copolymer. As can be seen in Figure 1, a decrease in the length of the hydrophobic substituent  
25 on the surfactant, from more hydrophobic cetyl- to less hydrophobic dodecyl-, decreases the stability of the complex more than ten-fold. This binding mechanism is, in particular, characteristic for surface active biological agents. See, for example,  
30 Florence and Attwood, *Physicochemical Principles of Pharmacy*, 2nd edn., p.180 et seq., Chapman and Hall, New York, 1988). For example, Figure 2 provides the binding isotherms for interaction of doxorubicin and rhodamine 123 with the copolymer of polyethylene  
35 oxide-*block*-poly(sodium methacrylate).

Formation of the electrostatic complexes

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between surfactants and P-type segments results in charge neutralization. As a result hydrophobicity of the complexed segments increases and aqueous solubility decreases. However, the preferred biological agent compositions remain in the aqueous solution due to the presence of the N-type segments linked to the P-type segments. By varying the relative lengths and amounts of the N-type and P-type blocks it is possible to vary the hydrophilic-lipophilic properties of the complexes formed between the surfactant and block copolymer and to optimize the solubility of the preferred compositions. It is preferred that the compositions of the present invention are water soluble at physiological conditions (pH, osmolarity, etc.) and temperatures. Figure 3 shows that binding of cetylpyridinium bromide to poly(sodium methacrylate) segment alone results in formation of a water-insoluble complex, whereas binding of the same surfactant to the block copolymer poly(ethylene oxide)-*block*-poly(sodium methacrylate) yields a water-soluble complex.

The compositions of the present invention normally form complexes of small size that are thermodynamically stable and do not aggregate after storing in solutions for a period of time on the order of weeks or months, depending on the type of polymer. The ability to produce particles of such limited size is important because small particles can easily penetrate into tissues through even small capillaries and enter cells via endocytosis. The preferred size of these particles is less than 500 nm, more preferred less than 200 nm, still more preferred less than 100 nm. These systems can be lyophilized and stored as a lyophilized powder and then re-dissolved to form solutions with the particles of the same size.

It is useful to consider the constituents

that make up the complexes of this invention in terms of a parameter referred to herein as charge ratio of the complex. The charge ratio of the complex, herein designated as " $\phi$ ", is the ratio of the net charge of the surfactant molecules bound with one block copolymer molecule to the net charge of the P-type segments in this block copolymer. By way of example, if the surfactant molecule has two positively charged groups and five negatively charged groups, it has a "net charge" of -3. Thus, if a surfactant with the net charge  $z_1$  binds to the oppositely charged P-type segments of the block copolymer, then the charge ratio is expressed as follows:

$$\phi = \frac{n \cdot z_1}{\gamma \cdot z_2 \cdot PD} \quad (1)$$

where  $n$  is the number of surfactant molecules bound to one block copolymer molecule,  $z_2$  is the net charge of the repeating unit of the P-type segment,  $PD$  is the degree of polymerization of the P-type segment, and  $\gamma$  is the number of P-type segments in the block copolymer molecule.

If  $\phi < 1$ , then the complex has the same charge sign as the P-type segments; if  $\phi > 1$ , the complex has the same charge sign as the surfactant; and if  $\phi = 1$ , the complex is electro-neutral. Therefore, by varying the molar ratio of the components in the compositions the charge of the particles formed can be changed from negative to positive and *vise versa*. See for example Figure 4. As a result various biological agents can be incorporated into such particles through combination of electrostatic and hydrophobic interactions. For example, the compositions from cationic surface active

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biological agents (e.g., adriamycin-14-naphtaleneacetate) and anionic block copolymer (e.g., polyethylene oxide-block-poly(sodium methacrylate)) at  $\phi > 1$  are positively charged. The compositions from

5 anionic surface active biological agents (e.g., indomethacin) and cationic copolymer (e.g., polyethyleneimine and polyethylene oxide) at  $\phi > 1$  are negatively charged.

It is further useful to introduce the

10 parameter characterizing the ratio of the net charges of surfactant to the net charges of the P-type segments of the block copolymer in the compositions of this invention. This parameter referred herein as composition of the mixture, and herein designated "Z" is expressed as follows:

15

$$Z = \frac{z_1 \cdot C_1}{\gamma \cdot z_2 \cdot PD \cdot C_2} \quad (2)$$

where  $z_1$ ,  $z_2$ ,  $\gamma$ , and PD have the same meaning as in equation (1) and  $C_1$  and  $C_2$  are the molar concentrations

20 of the surfactant and block copolymer in the mixture. While not wishing to be bound to any particulate theory, it is believed that the relationship between the charge ratio of the complex and composition of the mixture is as follows,  $\phi \geq Z$ . This means that  $n \geq C_1 C_2$ ,

25 i.e., the number of surfactant molecules bound to one block copolymer molecule is not less than the ratio of the molar concentrations of the surfactant and copolymer in the mixture. Further, when Z is less than 1, preferably less than 0.5,  $n > C_1 C_2$ , i.e., the

30 number of surfactant molecules bound to one block copolymer molecule is more than the ratio of the molar concentrations of the surfactant and block copolymer

in the mixture. The reason for the behavior expressed by those relationships is that the binding of surfactant molecules to the P-type segments of the block copolymer is enhanced by the presence of the molecules of surfactant already bound to the same block copolymer. Therefore, those relationships reflect the cooperative binding mechanism between the surfactant and block copolymers of the current invention.

Under certain conditions the particles of the complex spontaneously form vesicles that contain internal aqueous volume. Various biologically active agents (for example, 3'-azido-3'-deoxythymidine, water soluble protease inhibitors, interleukins, insulin and the like) can be physically entrapped into the internal aqueous volume of such vesicles. The optimal conditions for the vesicle formation is determined by the composition of the mixture, so that the vesicles form when Z is more than about 0.1 and less than 100, preferably more than 0.4 and less than 20, still more preferably more than 0.7 less than 10.

Furthermore, the compositions of present invention can solubilize hydrophobic biological agents (e.g., paclitaxel) through nonpolar interactions in the microphase formed by the hydrophobic groups of the surfactant.

One important aspect of the current invention is that electrostatic interactions between the charged groups of the biologically active surface active agent and repeating units of the P-type segments of the block copolymer are pH-dependent. For example, Figure 5 shows the pH-dependency of the reaction between cetylpyridinium bromide and the copolymer of polymethacrylic acid and polyethylene oxide. It is preferred that either the P-type segment of the block copolymer or the surfactant or both the

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P-type segment and the surfactant represent a weak acid or weak base. The preferred compositions formed are pH-dependent in the pH-range of from about pH 2.0 to about pH 10.0, more preferably in the pH-range of from about pH 3.0 to about pH 9.0, still more preferably in the pH-range of from about pH 4.0 to about pH 8.0. Dissociation of the biologically active surfactant and block copolymer complexes as a result of the pH change is characterized by step-type behavior, with more cooperative systems revealing sharper pH dependencies. Preferably these complexes dissociate when the pH change is about 3.0 units of pH, more preferably about 2.0 units of pH, still more preferably about 1.0 unit of pH. Since the biologically active surfactant and block copolymer are linked to each other through non-covalent interactions, dissociation of the complex results in the release of the biological agent. The complexes between the surfactants and block copolymers are stable in the pH range of from about pH 5.5 to about pH 8.5, preferably in the pH range of from about pH 6.5 to about pH 7.5. These complexes, however, easily dissociate when the pH shift occurs in the target tissue or cell, or other target site, which enables site-specific release of the biological agents. To facilitate for the release of the surfactant active biological agent from the compositions of the first embodiment the total amount of net charge of these biological agents is no more than about 5, more preferably no more than 4, still more preferably no more than 3.

The compositions of the present invention allow diverse routes of administration, including but not limited by parenteral (such as intramuscular, subcutaneous, intraperitoneal, and intravenous), oral, topical, otic, topical, vaginal, pulmonary, and

ocular. These compositions can take the form of tablets, capsules, lozenges, troches, powders, gels, syrups, elixirs, aqueous solutions, suspensions, micelles, emulsions and microemulsions.

5 Conventional pharmaceutical formulations are employed. In the case of tablets, for example, well-known carriers such as lactose, sodium citrate, and salts of phosphoric acid can be used. Disintegrants such as starch, and lubricating agents  
10 such as magnesium stearate, sodium lauryl sulfate and talc, as are commonly used in tablets, can be present. Capsules for oral administration can include diluents such as lactose and high molecular weight polyethylene glycols. When aqueous suspensions are required for  
15 oral use, the conjugate can be combined with emulsifying and suspending agents. For parenteral administration, sterile solutions of the conjugate are usually prepared, and the pH of the solutions are suitably adjusted and buffered. For intravenous use,  
20 the total concentration of solutes should be controlled to render the preparation isotonic. For ocular administration, ointments or droppable liquids may be delivered by well-known ocular delivery systems such as applicators or eyedroppers. Such compositions  
25 can include mucomimetics such as hyaluronic acid, chondroitin sulfate, hydroxypropyl methylcellulose or polyvinyl alcohol, preservatives such as sorbic acid, EDTA or benzylchromium chloride, and the usual quantities of diluents and/or carriers. For pulmonary  
30 administration, diluents and/or carriers will be selected to be appropriate to allow for formation of an aerosol.

The following examples are provided to describe the invention in further detail. These  
35 examples are intended merely to illustrate specific embodiments of the compositions and methods of the

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invention and should in no way be construed as limiting the invention.

5 The ability of the biologically active compositions of the invention to alter the biological profile and activity of biological agents can be conveniently observed in a number of experimental models, as described in the following two examples.

#### EXAMPLE 1

10 The multidrug resistant KBv cell line (vinblastine resistant human epidermoid carcinoma) which express high levels of glycoprotein P (P-gp) efflux pump (Gervasoni et al., *Cancer Research*, 1991, 51: 4955) can be used to evaluate the effects of  
15 present compositions on doxorubicin cytotoxicity. KBv cells were maintained *in vitro* as a monolayer culture in RPMI 1640 media supplemented with 10% fetal bovine serum. The cells were cultured in the drug-free medium for minimum four passages prior to experimental use.  
20 The cells were harvested by trypsinization, plated at 2000 to 3000 cells/well in fresh medium into 96-well microtiter plates and cultured for 1 to 2 days to allow the reattachment. The doxorubicin with or without 0.02 % polyethylene oxide-*block*-poly(sodium  
25 methacrylate) was subsequently added at various concentrations and the cell monolayers were incubated for 4 hours at 37°C with 5% carbon dioxide. After incubation, the cell monolayers were washed three times with D-PBS and cultured for 4 days in RPMI 1640  
30 supplemented with 10% FBS. The drug cytotoxicity was determined by a standard XTT assay (Scudievo, et al., *Cancer Research*, 1988, 48, 4827). Briefly, the sterile 1 mg/ml XTT solution in RPMI 1640 containing 5 µl/ml of 1.54 µg/ml phenazine methasulfate solution in  
35 sterile PBS was added to the cells (50 µl/well in 200 µl of medium) and incubated for 4 to 16 hours at 37°C

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and 5% CO<sub>2</sub>. The absorbance at  $\lambda$ 420 was determined using a microplate reader. All the experiments were carried out in triplicates. SEM values were less than 10% ( $P < 0.05$ ). The values of IC<sub>50</sub> were determined from the dose response curves. The results are as follows:

Composition studied	IC <sub>50</sub> , ng/ml
Doxorubicin in assay buffer	5
Doxorubicin in 0.02% polyethylene oxide-block-poly(sodium methacrylate)	0.1

The above data demonstrate that the present composition chemosensitize the multidrug resistant cancer cells with respect to MDR drug.

#### EXAMPLE 2

The following experiment evaluated the effects of compositions of this invention on uptake of rhodamine 123 in human intestinal epithelial cells Caco-2. These cells are expressing P-gp that controls permeability of the cells with respect to a broad class of pharmaceutical agents (Thiebault, et al. *Proc. Natl. Acad. Sci. USA* 1987, 84: 7735). Rhodamine 123 is a specific probe for the effects on the P-gp efflux system, which is commonly used for evaluation of the P-gp efflux system in cancer and normal cells (Jancis et al., *Mol. Pharmacol.* 1993, 43: 51; Lee et al., *Mol. Pharmacol.* 1994, 46: 627). From a drug delivery standpoint, blocking P-gp function in intestinal epithelial cells could have a significant impact. The Caco-2 cells were cultured in DMEM supplemented with 10 % fetal bovine serum. The Caco-2 cell monolayers were grown in 24-well culture plates and used in rhodamine uptake experiments after

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reaching confluency. Confluency of all cell monolayers was determined by visual inspection using an inverted light microscope. 3.2  $\mu$ M rhodamine 123 was formulated with 0.01 % solution of the polyethylene oxide-*block*-poly(sodium methacrylate) in assay buffer of the following composition: NaCl (122 mM), NaHCO<sub>3</sub> (25 mM), glucose (10 mM), KCl (3 mM), MgSO<sub>4</sub> (1.2 mM), K<sub>2</sub>HPO<sub>4</sub> (0.4 mM), CaCl<sub>2</sub> (1.4 mM) and HEPES (10 mM). The uptake of rhodamine 123 in Caco-2 cell monolayers in presence and absence of polyethylene oxide-*block*-poly(sodium methacrylate) was examined at 37°C over a period of 60 minutes. After a thirty-minute pre-incubation at 37°C the assay buffer was removed and 3.2  $\mu$ M rhodamine 123 with or without 0.01% polyethylene oxide-*block*-poly(sodium methacrylate) were added to the monolayers. These samples were exposed to the monolayers at 37°C for 90 minutes and uptake then stopped by removing the medium and washing the Caco-2 monolayers three times with 0.5 ml ice-cold PBS. The Caco-2 monolayers were solubilized in 1.0% Triton X-100 (0.5 ml) and aliquots were removed for determining cell-associated rhodamine fluorescence and protein content. Rhodamine 123 fluorescence is determined at  $\lambda_{ex}$  = 488 nm and  $\lambda_{em}$  = 550 nm using Shimadzu 5000 spectrofluorimeter; and protein content is determined using the Pierce BCA method. The concentration of rhodamine 123 in the Caco-2 lysate solution is determined by construction of standard curves. Data from the uptake studies are expressed as amount of cell-associated rhodamine/mg protein. Each data point represents the mean  $\pm$  SEM of 4 monolayers. The results are as follows:

Composition studied	uptake, nmol/mg
Rhodamine 123 in assay buffer	2.31 $\pm$ 0.48

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Rhodamine 123 in 0.01% polyethylene oxide- <i>block</i> - poly(sodium methacrylate)	5.82 $\pm$ 1.32
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5

The above data demonstrate that present composition enhances transport of MDR drug into cells expressing P-gp efflux system and that this formulation increases drug efficacy. A similar increase is observed in MDR cancer cells. Further, a similar increase is observed in hepatocytes and brain microvessel endothelial cells suggesting that present compositions can be used effectively to deliver drugs in tumours, in liver, across intestinal barrier and blood brain barrier.

### EXAMPLE 3

The effects of the present compositions on the transport of biologically active agents across biological barriers, such as intestinal can be conveniently demonstrated using the cell monolayers polycarbonate grown on membrane inserts. See, for example, Nerurkar et al., *Pharm Res.* 1996, 13: 528). The confluent Caco-2 monolayers grown on the polycarbonate membrane inserts were preincubated in culture media as described above. For both the preincubation period and the actual permeability experiments, 1.5 ml of media was placed on the luminal (donor) side of the monolayer and 2.6 ml of media is placed on the abluminal (receiver) side. The permeability of rhodamine 123 was determined by adding 3.2  $\mu$ M of R123 with or without 0.01% polyethylene oxide-*block*-poly(sodium methacrylate) to the donor side of the Caco-2 monolayer. At various times (0-90 minutes) 100  $\mu$ l samples of the receiver compartment were taken. Each sample removed was replaced with an

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equal volume of assay buffer. The samples were then assayed for rhodamine 123 by fluorescence spectrophotometry as described previously. To evaluate the integrity of the Caco-2 monolayers a small amount of [<sup>3</sup>H]manitol (0.5  $\mu$ Ci/ml) will be added to the apical compartment at the start of each permeability experiment. Since manitol does not readily cross the Caco-2 monolayers, this particular marker also determines the effects of the present compositions on overall Caco-2 monolayer integrity. The data from these experiments will be analyzed by graphing the amount of rhodamine 123 that appears in the receiver solution vs. time. Each data point represents the mean  $\pm$  SEM of 4 monolayers. The results are as follows:

Composition studied	Permeability, arb. Units				
	0.5 min	15 min	30 min	60 min	90 min
Rhodamine 123 in assay buffer	0.004 $\pm$ 0.002	0.032 $\pm$ 0.003	0.074 $\pm$ 0.005	0.176 $\pm$ 0.013	0.264 $\pm$ 0.018
Rhodamine 123 in block copolymer	0.009 $\pm$ 0.001	0.040 $\pm$ 0.008	0.122 $\pm$ 0.033	0.286 $\pm$ 0.040	0.505 $\pm$ 0.080

The above data demonstrate that present composition enhances permeability of a surfactant biological agent in intestinal barrier.

The following examples further illustrate the nature of this invention.

#### EXAMPLE 4

A. Block copolymer of *tert*-butyl methacrylate and ethylene oxide used in this study was prepared by sequential anionic polymerization generally following the previously published procedure (Wang et al., *J. Polym. Sci., Part A: Polym. Chem.*

1992, 30: 2251). The block lengths in copolymer were 176 for the PEO and 186 for tert-butyl methacrylate segments respectively. This copolymer was hydrolyzed to obtain the polyethylene oxide-*block*-polymethacrylic acid as described by Wang et al. (*J. Polym. Sci., Part A: Polym. Chem.* 1992, 30: 2251). The polyethylene oxide-*block*-poly(sodium methacrylate) was prepared by redissolving the acid form of the copolymer in tetrahydrofuran : methanol mixture (95:5 v/v) and adding NaOH in methanol. The precipitate containing polyethylene oxide-*block*-poly(sodium methacrylate) was filtered and washed with methanol, then redissolved in water and freeze dried. The concentration of carboxylate groups in the copolymer sample was estimated by potentiometric titration.

B. The binding isotherms of cetylpyridinium bromide (Sigma Co.) and dodecylpyridinium bromide (Sigma Co.) with the polyethylene oxide-*block*-poly(sodium methacrylate) copolymer were determined potentiometrically by using the following ion-selective electrode: Ag/AgCl | 1 M NH<sub>4</sub>NO<sub>3</sub> agar bridge | reference solution (surfactant, 2.5·10<sup>-4</sup> M) | PVC membrane | sample solution | 1 M NH<sub>4</sub>NO<sub>3</sub> agar bridge | Ag/AgCl. The preparation of PVC ion-selective electrode is described elsewhere (Shirahama et al., *Bull. Chem. Soc. Jpn.* 1981, 54: 375; Shirahama and Tashiro, *Bull. Chem. Soc. Jpn.* 1984, 57: 377; Mel'nikov et al., *J. Am. Chem. Soc.* 1995, 117: 9951). The electromotive force (emf) of the cell was measured with a digital Radiometer PHM-83 pH-meter. The electrode exhibited a good Nernstian response over the range of surfactant concentrations examined. Binding isotherms were obtained by titration of 5·10<sup>-4</sup> base-mole/L polyethylene oxide-*block*-poly(sodium methacrylate) solutions with the solution of the corresponding surfactant. The

- 40 -

results were corrected for the decrease in the copolymer concentration as a result of the addition of the surfactant solution. The fraction of occupied binding sites  $\beta$  was defined as follows

5

$$\beta = (C_t - C_f) / C_i \quad (3)$$

where  $C_t$  is the total concentration of added surfactant,  $C_f$  is the concentration of the free surfactant,  $C_f$  determined using the calibration curves (i.e., linear plots "emf vs. log  $C_t$ " determined in the absence of polymer and  $C_t < \text{CMC}$ ), and  $C_i$  is the concentration of ionic groups of the block copolymer. The results obtained for binding of cetylpyridinium bromide and dodecylpyridinium bromide are presented in Figure 1.

15

#### EXAMPLE 5

The binding isotherms of doxorubicin (Sigma Co.) to polyethylene oxide-*block*-poly(sodium methacrylate) copolymer were determined using fluorescent spectroscopy. Briefly, the fluorescence emission intensity of doxorubicin at 556 nm (excitation 471 nm.) was determined in 10 mM phosphate buffer, pH 7.4 with and without the block copolymer. In the presence of block copolymer the fluorescence of doxorubicin was quenched. The fraction of occupied binding sites  $\beta$  was defined as follows

20

25

$$\beta = \frac{I_o - I}{I_o} \cdot \frac{C_t}{C_i} \quad (4)$$

30

where  $I_o$  and  $I$  are fluorescence emission intensities without and with the block copolymer,  $C_t$  is the total

- 41 -

concentration of added surfactant, and  $C_i$  is the concentration of ionic groups of the block copolymer. The results obtained for binding of doxorubicin to polyethylene oxide-*block*-poly(sodium methacrylate) are presented in Figure 2 (curve 1).

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EXAMPLE 6

Following the procedure of Example 2 but replacing doxorubicin with rhodamine 123 (Sigma Co.), conducting fluorescence measurements at excitation 505 nm and emission 522 nm, and using

$$\beta = \frac{I - I_o}{I_{\max} - I_o} \cdot \frac{C_t}{C_i} \quad (5)$$

where  $I_{\max}$  is the maximal fluorescence at saturating concentrations of the block copolymer there is obtained the binding isotherm in Figure 2 (curve 2).

EXAMPLE 7

Polyethylene oxide-block-poly(sodium methacrylate) was the same as described in Example 4. The homopolymer polymethacrylic acid with a  $P_w=930$  was obtained by radical polymerization (Lipatov, and Zubov, Vysokomol. Soedin., Ser. A. 1959, 1:88). Complexes formed between these polymers and cetylpyridinium bromide (Sigma Co.) were studied using turbidity measurements. At base molar concentrations of anionic polymers  $1.08 \cdot 10^{-3}$  base-mole/L; temperature  $25^\circ\text{C}$ , and pH 9.2. The turbidity measurements were carried out using a Shimadzu UV160 spectrophotometer at 420 nm after equilibration of the system typically for 3 minutes. The data are reported in Figure 3 as  $(100-T)/100$ , where T is transmission (%) for complexes from polyethylene oxide-block-poly(sodium methacrylate) and poly(sodium methacrylate).

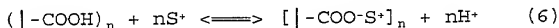
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EXAMPLE 8

The complexes between N-cetylpyridinium bromide and polyethylene oxide-block-poly(sodium methacrylate) were prepared in  $8 \cdot 10^{-4}$  base-mole/L solution of the block copolymer at 25°C and pH 9.2. The  $C_t/C_i$  was varied from 0.01 to 5, where  $C_t$  is the total concentration of added surfactant, and  $C_i$  is the concentration of ionic groups of the block copolymer. Electrophoretic mobility (EPM) measurements were performed at 25°C with an electric field strength of 15-18 V/cm by using "ZetaPlus" Zeta Potential Analyzer (Brookhaven Instrument Co.) with 15 mV solid state laser operated at a laser wavelength of 635 nm. The zeta-potential of the particles was calculated from the EPM values using the Smoluchowski equation. Effective hydrodynamic diameter was measured by photon correlation spectroscopy using the same instrument equipped with the Multi Angle Option. All solutions were prepared using double distilled water and were filtered repeatedly through the Millipore membrane with pore size 0.22  $\mu$ M. The sizing measurements were performed at 25°C at an angle of 90°. The results are presented in Figure 4.

EXAMPLE 9

The interaction between a cationic surfactant ( $S^+$ ) and a weak polyacid represents an ion exchange reaction resulting in the release of the protons in accordance with the following scheme:



The equilibrium of this reaction for the mixtures of cetylpyridinium bromide with polyethylene

oxide-block-poly methacrylic acid was studied at different pH by potentiometric titration (see, for example, Kabanov, Polymer Science 1994, 36:143). Polyethylene oxide-block-poly methacrylic acid was synthesized as described in Example 4. The alkali titration curves were obtained for the mixtures of N-cetylpyridinium bromide (Sigma Co.) with polyethylene oxide-block-poly methacrylic acid. The total concentration of the surfactant was equal to the concentration of the ionizable groups of the polyacid. The degree of conversion,  $\theta$ , in the ion exchange reaction (5) was determined from original titration curves on the assumption that all alkali is consumed for neutralization of protons released as a result of this reaction. For a weak polyacid  $\theta$  at a given pH is expressed as follows

$$\theta = (m_b/V + [H^+] - \sqrt{K_a C_o}) / C_o, \quad (7)$$

where  $M_b$  is the number of moles of the added base,  $V$  is the current volume of the reaction system,  $K_a$  is the characteristic dissociation constant,  $C_o$  is the base-molar concentration of the polyacid. The results are presented in Figure 5.

#### EXAMPLE 10

The existence of internal aqueous volume in the particles of the complex formed between the block copolymers and surfactants of the present invention can be conveniently demonstrated using a water-soluble fluorescent dye, 5,6-carboxyfluorescein. See, for example, Parker, Photoluminescence of Solutions; Elsevier: New York, p.303 et seq., 1968. The complex between N-cetylpyridinium bromide and polyethylene

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oxide-block-poly(sodium methacrylate) is prepared as described in Example 8 at Ct/Ci = 1 replacing the solution of the copolymer in water for the solution of the same copolymer in 10 mM of 5,6-carboxyfluorescein (Sigma Co.). Briefly, 0.87 ml of the aqueous solution of 10 mM 5,6-carboxyfluorescein, pH 7.4 is mixed with 50  $\mu$ l of 0.039 M solution of polyethylene oxide-block-poly(sodium methacrylate) and 80  $\mu$ l of 0.025 M N-cetylpyridinium bromide solution. After 30 minutes incubation at room temperature the particles of the complex were separated from the dye remaining in the external volume by gel permeation chromatography using Sephadex G-25 medium (Pharmacia Biotech) equilibrated with the solution of 0.01 mM N-cetylpyridinium bromide. The fluorescence emission of 5,6-carboxyfluorescein in the solutions obtained is determined at the excitation wavelength 495 nm and 25°C using Shimadzu 5000 spectrofluorimeter. The maximum of fluorescence emission of the dye in this system was observed at 517.2 nm (slit 1.5 nm) which corresponds to the emission maximum of the free dye in the absence of the particles. Addition of 40  $\mu$ l of 10% (v/v) aqueous Triton X-100 (Sigma Co.) to this system results in a sharp increase in the fluorescence intensity resulting from the release of the concentrated dye from the internal aqueous cavity of the particles. This suggests that the particles represent the vesicles with an internal aqueous volume.

30

#### EXAMPLE 11

The complex between N-cetylpyridinium bromide and polyethylene oxide-block-poly(sodium methacrylate) was prepared as described in Example 10 replacing 10 mM 5,6-carboxyfluorescein solution with 0.1 mM solution of calcein (Sigma Co.). The particles

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of this complex were separated by gel permeation chromatography as described in Example 10. The fluorescence emission intensity of calcein was determined at the emission and excitation wavelengths 490 nm and 520 nm respectively. 2  $\mu$ l of  $\text{CoCl}_2$  solution and 40  $\mu$ l of 10% Triton X-100 were added to this system in different order to quench fluorescence outside the vesicles. Addition of  $\text{CoCl}_2$  resulted in the decrease of the fluorescence in this system to 3 % of the initial fluorescence. When Triton X-100 was added after  $\text{CoCl}_2$  the fluorescence was further decreased to 1 % of the initial value. In contrast, when Triton X-100 was added without prior addition of  $\text{CoCl}_2$  no change in the fluorescence was recorded. When  $\text{CoCl}_2$  solution was added after the Triton X-100 solution the fluorescence was decreased to about 1 % of the initial value. This suggests formation of the vesicles with an internal volume of about 2 % of the total volume.

#### EXAMPLE 12

A polyethyleneglycol (8,000)-polyethylene imine (m.w. 2,000) copolymer was synthesized as previously reported by Vinogradov et al. (Pharm. Res., 14: S-641). The complex between the polyethylene glycol-polyethyleneimine copolymer and anionic surfactant, Aerosol(OT (Sigma Co.) was obtained at  $C_t/C_i = 1$ , where  $C_t$  is the total concentration of added surfactant, and  $C_i$  is the concentration of ionic groups of the block copolymer. The size of the particles formed, determined by dynamic light scattering as described in Example 8, equals 57 nm.

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EXAMPLE 13

The complex between the polyethylene glycol-polyethyleneimine copolymer, exemplified above, and fatty acid salt, oleic acid sodium salt (Sigma Co.) was obtained at  $C_t-C_i=1$  in sodium phosphate buffer (SPB), 10 mM, pH 6.0 by simple mixing of the copolymer solution in the same buffer and fatty acid salt solution in methanol. The final content of methanol in the complex solution was 3%. The size of the particles formed, determined by dynamic light scattering as described in Example 8, above, was 54 nm.

EXAMPLE 14

The complex between the polyethylene glycol-polyethyleneimine copolymer, mentioned above, and fatty acid salt, oleic acid sodium salt was obtained at  $C_t-C_i=1$  in sodium phosphate buffer (SPB), 10 mM, pH 7.4, as described in Example 13, above. The size of the particles formed, determined by dynamic light scattering as described in Example 8, above, was 44 nm.

EXAMPLE 15

The complex between the polyethylene glycol-polyethyleneimine copolymer, mentioned above, and fatty acid salt, oleic acid sodium salt was obtained at  $C_t-C_i=1$  in TRIS-buffer, 10 mM, pH 8.2, as described in Example 13, above. The size of the particles formed, determined by dynamic light scattering as described in Example 8, above, was 56 nm.

EXAMPLE 16

The complex between the polyethylene glycol-polyethyleneimine copolymer and retinoic acid (Aldrich Co.) was obtained at  $C_t-C_i=1$  in sodium phosphate buffer

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(SPB), 10 mM, pH 7.4. The solution of retinoic acid in water/methanol (60:40, v/v) mixture containing sodium hydroxide was added to the copolymer solution in the SPB. The final content of methanol in the complex solution was 5%. The additional absorption band ( $\lambda_{\text{max}}=306$  nm) in the UV-vis spectrum of retinoic acid in the presence of copolymer was found to be comparable to that of pure retinoic acid at the same conditions ( $\lambda_{\text{max}}=343$  nm).

#### EXAMPLE 17

42.8 mg of nonafluoropentanoic acid (Aldrich Co.) and 1 mg of Taxol were mixed in 50  $\mu$ l of ethanol containing sodium hydroxide ( $2.84 \times 10^{-4}$  mole). This mixture was added to 1 ml of the complex between the polyethylene glycol-polyethyleneimine copolymer and oleic acid sodium salt prepared as described in Example 13, above. After stirring overnight, the sample was centrifuged 10 minutes at 13000 RPM. 20  $\mu$ l of supernatant was added to 1 ml of methanol and UV spectra were recorded. The Taxol concentration was calculated from the absorbency at 227 nm ( $\epsilon=44,359$  ml/mg). The extinction coefficient was estimated in the presence of fluoroorganic component in methanol. The degree of Taxol solubilization was 74.4%. The size of the complex particles loaded with the Taxol/Fluoroorganic compound mixture determined by dynamic light scattering as described in Example 8, above, was 61 nm.

While certain embodiments of the present invention have been described and/or exemplified above, various other embodiments will be apparent to those skilled in the art from the foregoing disclosure. The present invention is, therefore, not limited to the particular embodiments described and/or

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exemplified, but is capable of considerable variation and modification without departure from the scope of the appended claims.

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**WHAT IS CLAIMED IS:**

1. A composition of matter comprising a  
supramolecular complex comprising as constituents a  
5 block copolymer, having at least one nonionic, water  
soluble segment and at least one polyionic segment,  
and at least one charged surfactant having hydrophobic  
groups, the charge of said surfactant being opposite  
10 to the charge of the polyionic segment of said block  
copolymer, the constituents of said complex being  
bound by interaction between said opposite charges and  
between surfactant hydrophobic groups, and with the  
proviso that when said complex comprises an anionic  
15 surfactant having a biological activity, said anionic  
surfactant has a net charge of no more than about 10.

2. A composition as claimed in claim 1  
wherein the ratio of the net charge of said surfactant  
to the net charge of the polyionic segment present in  
20 said block copolymer constituent of said complex is  
between about .01 and about 100.

3. A composition as claimed in claim 2,  
wherein said charge ratio is between about 0.1 and  
25 about 10.

4. A composition as claimed in claim 2,  
wherein the polyionic segment of said block copolymer  
is polyanionic.

5. A composition as claimed in claim 4,  
wherein the nonionic segment of said block copolymer  
is selected from the group consisting of  
polyetherglycols, copolymers of ethylene oxide and  
30 propylene oxide, polysaccharides, homopolymers and  
copolymers of vinyl compounds selected from the group

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consisting of acrylamide, acrylic acid esters, methacrylamide, methacrylic acid esters, N-(2-hydroxypropyl) methacrylamide, vinyl alcohol, vinyl pyrrolidone, vinyl triazole, or the N-oxide of vinylpyridine, polyorthoesters and polyamino acids.

6. A composition as claimed in claim 4 in the form of vesicles.

7. A composition as claimed in claim 4, wherein said polyanionic segment is selected from the group consisting of polymethacrylic acid and its salts, polyacrylic acid and its salts, copolymers of methacrylic acid and its salts, copolymers of acrylic acid and its salts, heparin, poly(phosphate), polyamino acid, polymaleic acid, polylactic acid, nucleic acid or carboxylated dextran.

8. A composition as claimed in claim 4, wherein said polyanionic segment is a homopolymer or a co-polymer prepared from a monomer which polymerizes to form a product with carboxyl pendant groups, said monomer being selected from the group consisting of acrylic acid, asparatic acid (amino acid), 1,4-phenylenediacrylic acid citraconic acid, citraconic anhydride, trans cinnamic acid, 4-hydroxy-3-methoxy cinnamic acid, p-hydroxy cinnamic acid, trans-glutaconic acid, glutamic acid (amino acid), itaconic acid, linoleic acid, linolenic acid, methacrylic acid, maleic acid, maleic anhydride, mesaconic acid, trans- $\beta$ -hydromuconic acid, trans-trans muconic acid, oleic acid, ricinoleic acid, 2-propene-1-sulfonic acid, 4-styrene sulfonic acid, trans-traumatic acid, vinylsulfonic acid, vinyl phosphate acid, vinyl benzoic acid, vinyl glycolic acid.

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9. A composition as claimed in claim 4,  
wherein said surfactant is selected from the group  
consisting of lipophilic quaternary ammonium salts,  
lipopolyamines, lipophilic polyamino acids, lipophilic  
5 primary-, secondary-, tertiary- and heterocyclic  
amines, lipophilic imidazoles, lipophilic piperidinium  
salts, lipophilic quinaldinium salts, lipophilic  
azonium and azolium salts, pH-sensitive cationic  
lipids, dicationic bolaform electrolytes or a mixture  
10 of said surfactants.

10. A composition as claimed in claim 4,  
further including a nonionic surfactant.

11. A composition as claimed in claim 10,  
wherein said nonionic surfactant is selected from the  
group consisting of dioleoyle  
phosphatidylethanolamine, dioleoyl  
phosphatidylcholine, or a mixture of said nonionic  
20 surfactants.

12. A composition as claimed in claim 2  
wherein the polyionic segment of said block copolymer  
is polycationic.

25 13. A composition as claimed in claim 12 in  
the form of vesicles.

14. A composition as claimed in claim 12,  
30 wherein said polycationic segment is selected from the  
group consisting of polyamino acid, alkanolamine esters  
of polymethacrylic acid, polyamines,  
polyalkyleneimines, polyvinyl pyridine and the  
quaternary ammonium salts of said polycationic  
35 segments.

15. A composition as claimed in claim 12, wherein said anionic surfactant is selected from the group consisting of alkyl sulfates, alkyl sulfonates, fatty acid soaps, salts of hydrox-, hydroperoxy-, polyhydroxy-, epoxy- fatty acids, salts of mono- and polycarboxylic acids, prostanoic acid and prostaglandines, leukotriens and lipoxines, alkyl phosphates, alkyl phosphonates, lipids, sodium-dialkyl sulfosuccinate, n-alkyl ethoxylated sulfates, cholate and desoxycholate of bile salts, perfluorocarboxylic acids, fluoroaliphatic phosphonates, fluoroaliphatic sulphates.

16. A composition as claimed in claim 1, wherein said surfactant is a biologically active agent.

17. A composition as claimed in claim 16, wherein said biologically active agent has a molecular mass of less than about 2000.

18. A method for preparing a composition of matter as claimed in claim 1, in the form of vesicles, said method comprising mixing a block copolymer, having at least one nonionic, water soluble segment and at least one polyionic segment, and a charged surfactant having hydrophobic groups, the charge of said surfactant being opposite to the charge of the polyionic segment of said block copolymer, the ratio of the net charge of said surfactant to the net charge of the polyionic segment present in said block copolymer being between about .01 and about 100, and with the proviso that when said surfactant is a biologically active agent, said agent has a net charge of no more than about 5.

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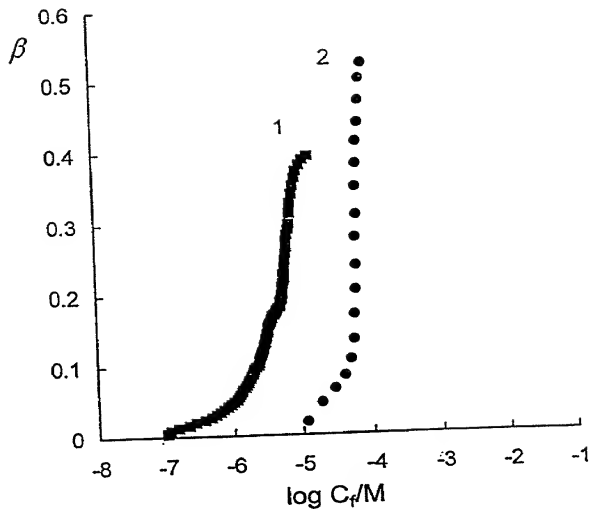


Figure 1

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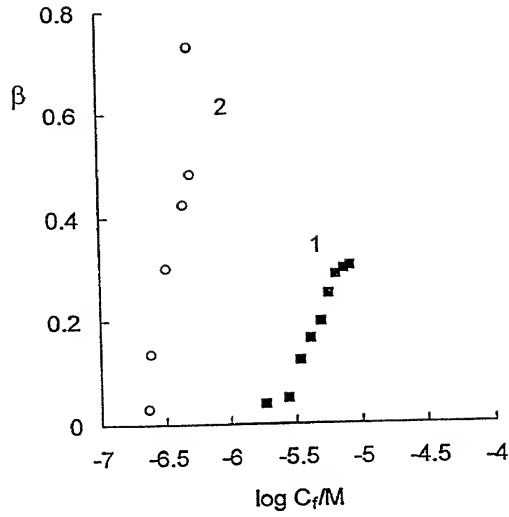


Figure 2

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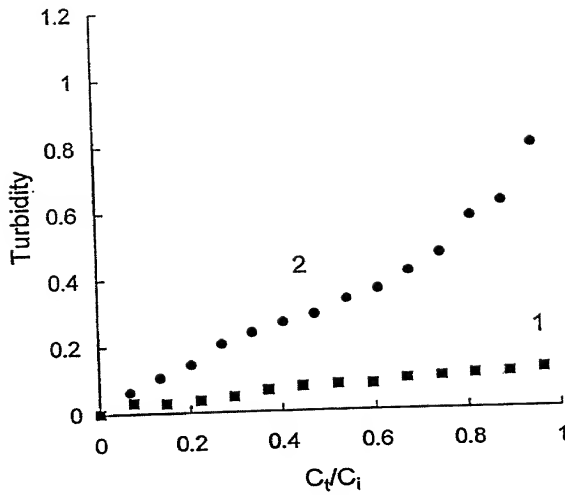


Figure 3

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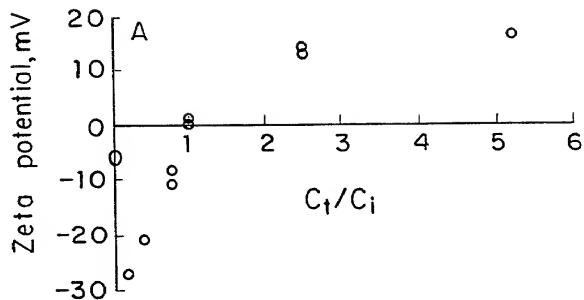


FIG. 4A

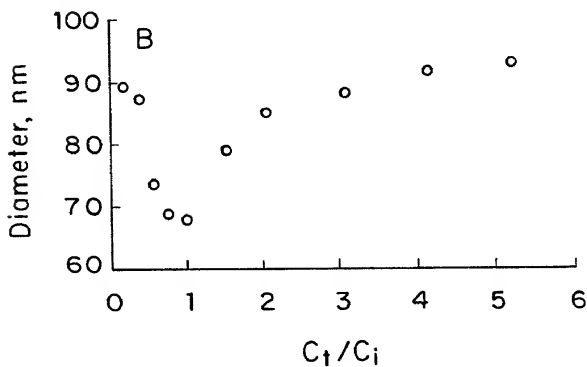
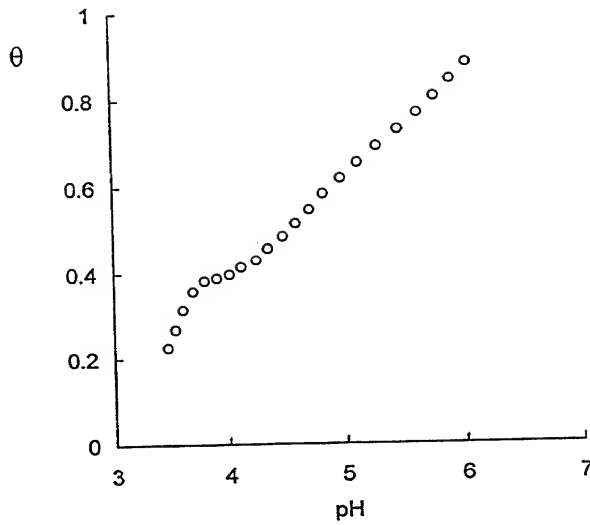


FIG. 4B

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**Figure 5**



## DECLARATION, POWER OF ATTORNEY AND POWER TO INSPECT

As a below named inventor, I hereby declare:

that my residence, post office address and citizenship are as stated below next to my name;

that I verily believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural inventors are named below) of the invention entitled: **COMPOSITIONS FOR DELIVERY OF BIOLOGICAL AGENTS AND METHODS FOR THE PREPARATION THEREOF**

the specification of which [check one(s) applicable]

☒ was filed 11 June 1998 as International Application No. PCT/US98/12139 (now U.S. Application No. 09/445,656)

☐ and was amended by Amendment filed \_\_\_\_\_ (if applicable); [or];

☐ is attached to this Declaration, Power of Attorney and Power to Inspect;

that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above; and

that I acknowledge my duty to disclose information which is material to the examination of this application in accordance with Rule 56(a) [37CFR§1.56(a)].

**CLAIM UNDER 35 USC §119(e):** I hereby claim the benefit under 35 USC §119(e) of any United States provisional applications listed below:

**Provisional Application No.**

60/053,000

**Filing Date**

**Day/Mo/Year**  
13 June 1997

**POWER OF ATTORNEY:** As inventor, I hereby appoint **DANN, DORFMAN, HERRELL AND SKILLMAN, P.C.** of Philadelphia, PA, and the following individual(s) as my attorneys or agents with full power of substitution to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: **Patrick J. Hagan, Reg. No. 27,643 and Kathleen D. Rigaut, Ph.D., Reg. No. 43,047.**

**POWER TO INSPECT:** I hereby give **DANN, DORFMAN, HERRELL AND SKILLMAN, P.C.** of Philadelphia, PA or its duly accredited representatives power to inspect and obtain copies of the papers on file relating to this application.

**SEND CORRESPONDENCE TO:** CUSTOMER NUMBER 000110.

**DIRECT INQUIRIES TO:** Patrick J. Hagan, Esq.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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60/053,000

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P. 3

As a below named inventor, I hereby declare:

that my residence, post office address and citizenship are as stated below next to my name;

that I verily believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural inventors are named below) of the invention entitled: COMPOSITIONS FOR DELIVERY OF BIOLOGICAL AGENTS AND METHODS FOR THE PREPARATION THEREOF

the specification of which (check one(s) applicable)

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that I acknowledge my duty to disclose information which is material to the examination of this application in accordance with Rule 56(c) (37CFR 1.56(a)).

CLAIM UNDER 35 USC §118(e): I hereby claim the benefit under 35 USC §118(e) of any United States provisional applications listed below:

Provisional Application No.

Filing Date

00/053,600

May/June/Year  
13 June 1997

POWER OF ATTORNEY: As inventor, I hereby appoint DANN, BOFFMAN, HERRELL AND SKILLMAN, P.C. of Philadelphia, PA, and the following individual(s) as my attorneys or agents with full power of execution to prosecute this application and in transact all business in the Patent and Trademark Office connected therewith: Patrick J. Hagan, Reg. No. 37,645 and Kathleen G. Rigaut, Ph.D., Reg. No. 43,947.

POWER TO INSPECT: I hereby give DANN, BOFFMAN, HERRELL AND SKILLMAN, P.C. of Philadelphia, PA or its duly accredited representative power to inspect and obtain copies of the papers on file relating to this application.

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First Middle Last

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Residence \_\_\_\_\_  
City State or Country

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